The Occurrences of Five Graptolites species in Linwe Formation, Mibayataung Area, Southern Shan State

Ye Yint Aung[1], Kaung Sithu[2], Yin Min Htwe [3], Chit Sein[4]

Abstract

The Llandovery (Early Silurian) Graptolites are well preserved in the Linwe Formation (Mibayataung Group). Generally, extensive outcrops of the Lower Paleozoic are exposed at the southeastern part of the study area. The fossil specimens were collected from the Linwe Formation (Early Silurian), near the Wagyimyaung village, Mibayataung area, Kalaw Township, Southern Shan State. Herein, the graptolite faunas consist of five species including *Monograptus convolutus, Monograptus priodon, Monograptus triangulatus, Monograptus turriculatus*, and *Petalograptus folium*. The graptolites assemblages are abundant in shale unit.

Keywords: Graptolite, Systematic Paleontology, Linwe Formation, Early Silurian

Introduction

Linwe Formation is widely distributed in the southeastern part of the Mibayataung area. Many previous workers (Brown and Sondhi, 1933; Reed, 1936; Myint Lwin Thein, 1973; Garson *et al*., 1974; Kyi Soe, 1983; Wolfart *et al*., 1984; Hla Thein, 1991; Chit Sein, 1998; Kaung Sithu, 2014; Ye Yint Aung, 2015; Ohmar Soe Yin *et al*., 2021) studied the stratigraphy and paleontology. A few workers have geologically studied in Mibayataung area before; even the paleontological records are still very limited and poor. The systematic investigation is less detail for graptolite faunas in the study area. Hence, the present study to identify systematic paleontology of graptolite in the Linwe Formation.

Location

The study area is located about 14.4 km (9 miles) south-southwest of Heho, Kalaw Township, and southern Shan State (Figure 1). It is also situated at the western part of the Inle Lake and it is demarcated between vertical grids 90 to 100 and horizontal grids 30 to 40 in one-inch topographic map sheet number 93D/14.

Figure (1) Location map of the Study area

Aims and Objectives

The present study aims to identify the systematic study and taxonomic classification of graptolite faunas in the Mibayataung area. The objectives of this work are the following:

(1) To describe the various lithology of the study area
(2) To review the stratigraphic position and stratigraphic columnar sections

1. Demonstrator, Department of Geology, Taungoo University
2. Lecturer, Department of Geology, Kalay University
3. Professor, Department of Geology, Taungoo University
4. Rector, Yangon University of Distance Education

(3) To find-out the Paleozoic faunas of Linwe Formation
(4) To update the graptolite assemblage of the study area

Materials and Methods

In this section, the general traverses have been made to understand the different lithologic units, geometry, and fossiliferous rock units from the area, depending on the use of one-inch topographic map. During this study in 2015, the stratigraphic columnar sections were made by using Jacob's Staff method to demarcate the precise lithologic boundaries to get the fossil distribution that will enable to describe the reconstruction of the exact succession of Paleozoic rocks from the study area. Fossil specimens were collected carefully packed together with tissue papers, cottons and rubber bands. Photos are taken by using canon camera and drawing by Surfer Software.

Regional Geologic Setting

The study section is located in the southern part of the Pindaya and Bawsaing ranges. Generally, Early Paleozoic strata are mainly covered with the marine invertebrate fauna in the Pindaya range (Figure 2). The rocks are cropped out on both the north and south flanks of the Mibayataung. The Early Paleozoic and Mesozoic rock units are well exposed in Pindaya and Bawsaing range, illustrated by Myint Lwin Thein (1973). It is composed of rock units ranging from Precambrian to Permo-carboniferous in age. The Early Paleozoic rock units are Chaung Magyi Group (Precambrian), Molohein Group (Cambrian), Pindaya Group (Ordovician), and Mibayataung Group (Silurian). Paleozoic to Mesozoic unit is Plateau Limestone Group (Upper Permian to Middle Triassic).

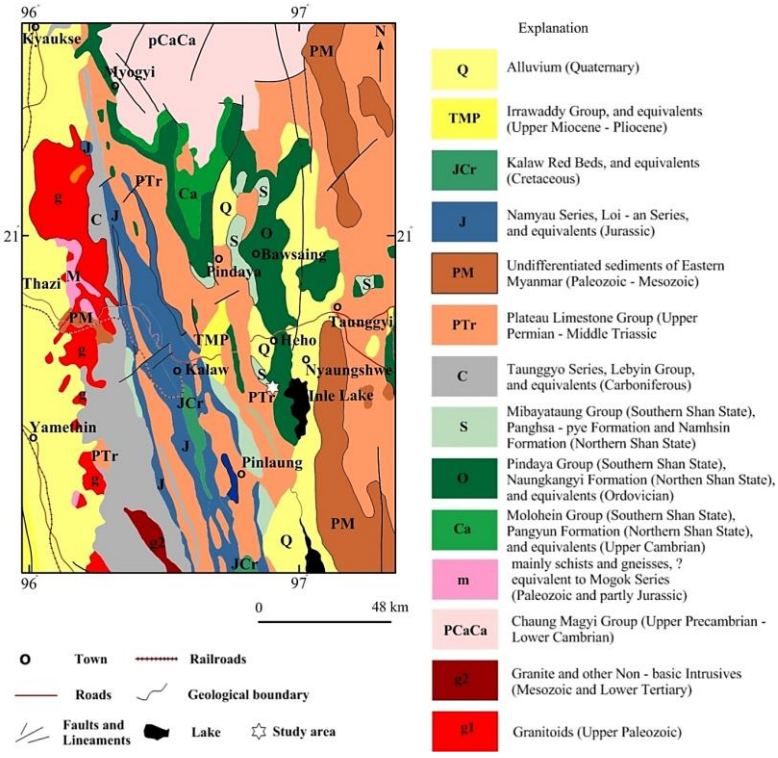

Figure (2) Regional geological map of the study area
(cited from a geological map of Myanmar, MGS, 2014)

Stratigraphy

Mainly, five lithostratigraphic units are found in the study area (Table 1). The stratigraphy of the Mibayataung area is as follows;

Table (1) The stratigraphic succession of the study area

Succession	Age
Alluvium	Quaternary
~~Unconformity~~~~~~~~~~~~~~~~~~~~~~~~~~	
Plateau Limestone Group	Permian to Middle Triassic
~~Unconformity~~~~~~~~~~~~~~~~~~~~~~~~~~	
Mibayataung Group	Silurian
Wabya Formation	Early to Late Silurian
Linwe Formation	Early Silurian
Pindaya Group	Ordovician
Nan-on Formation	Late Ordovician
Wunbye Formation	Middle Ordovician

Linwe Formation

Name derivation

The name was first given by Myint Lwin Thein (1973), after the Linwe village about the 24 km (15 miles) northeast of Ywa-ngan Township, southern Shan State. Type section is located grid co-ordinates (085728) on Topographic map no. 93 C/12. This formation is widely distributed at both Pindaya and Bawsaing ranges and also at the Taunggyi range and Taunggyi crag. The total thickness of the formation at the type section is 526 m (1773 feet).

Distribution

This formation is mainly distributed at the central part of the study area. Linwe Formation is also exposed at the southeastern part of Mibayataung monastery. Example localities are southeast of Mibayataung (357964), and west of Wagyimyaung (366978) by Chit Sein (1998). This formation is trending nearly NNW-SSE and the northern extension of the rocks are limited by fault.

Lithology

This formation mainly composed of hard, flaggy, brittle, brightly colour, red, pink or purplish and grey, argillaceous limestones, and calcareous shales with a highly developed phacoidal texture. *Michelinoceras* sp. and ostracods are mainly observed in the area. Usually they contain the remains of large crinoid stems and numerous specimens of orthoceras nautiloids. Locally, they are interbedded with strata of yellow, sandy mudstones with poorly preserved fossils.

Linwe Formation of the Mibayataung area is trending NNW-SSE direction and parallel to the Nan-on Formation. In the study area, Linwe Formation can be discriminated into two distinct units:

(II) Graptolite shale

(I) Phacoidal limestone

(I) Phacoidal limestone

The rocks of this unit are mainly made up of phacoidal textural limestone in the study area. These limestones can be subdivided into two subunits such as purple phacoidal limestone and grey phacoidal limestone.

(a) Purple phacoidal limestone

Purple phacoidal limestone occupies the basal part of the Linwe Formation and its lower boundary is in contact with upper boundary of Nan-on Formation of buff colour siltstone. Purple phacoidal limestone is mainly composed of purple colour, medium to coarse-grained, thick-bedded phacoidal textured limestone (Figure 3). These purple phacoidal limestones intercalated with the calcareous siltstone and shale in the upper part. *Michelinoceras* sp., crinoid stems, shell fragments are characteristic faunas in this unit.

(b) Grey phacoidal limestone

Grey phacoidal limestone consists of hard, flaggy, grey colour, medium to coarse-grained, medium to thick-bedded phacoidal limestone (Figure 4). This subunit is overlain by the lower part of Plateau Limestone Group. The fossils of *Michelinoceras* sp., inclined burrow, crinoid stems, and other shell fragments are found in this subunit.

Figure (3) Purple phacoidal limestone of the Linwe Formation at the south-south east of Mibayataung monastery (20˚ 35' 21.0" N, 96˚ 47' 47.4" E) Photo facing -SE

Figure (4) Grey phacoidal limestone of Linwe Formation at the northwestern part of Wagyimyaung village (20˚ 34' 39.2" N, 96˚ 48' 49.9" E) Photo facing - SE

(II) Graptolite shale

The graptolite shale is mainly composed of grey colour, sub-indurated, slaty shale with wavy and parallel laminations (Figures 5 & 6).

Figures (5 & 6) The exposure nature of graptolite shale of the Linwe Formation about ½ mile southeastern part of Mibayataung monastery (20˚ 35' 45.0" N, 96˚ 47' 56.1" E) Photo facing - NE

The thickness of this shale is 64 meters (Figures 7 & 8). This unit is a widely distributed at the northeastern part of the Mibayataung monastery. The graptolites, *M. convolutus, M. priodon, M. triangulatus, M. turriculatus, Petalograptus folium* are abundant in this subunit. The composite section is 75 meters' thickness and it consists of purple phacoidal limestone (Upper part), graptolite shale (Middle part), and grey phacoidal limestone units (Lower part) (Figure 9).

Stratigraphic Relationship

The lower boundary of Linwe Formation is in contact with the last appearance of buff colour siltstone of the Nan-on Formation. The upper boundary is marked by the first appearance of the Wabya Formation in the study area. However, the upper boundary of the Linwe Formation is unconformable in contact with the Plateau Limestone near the Mibayataung monastery.

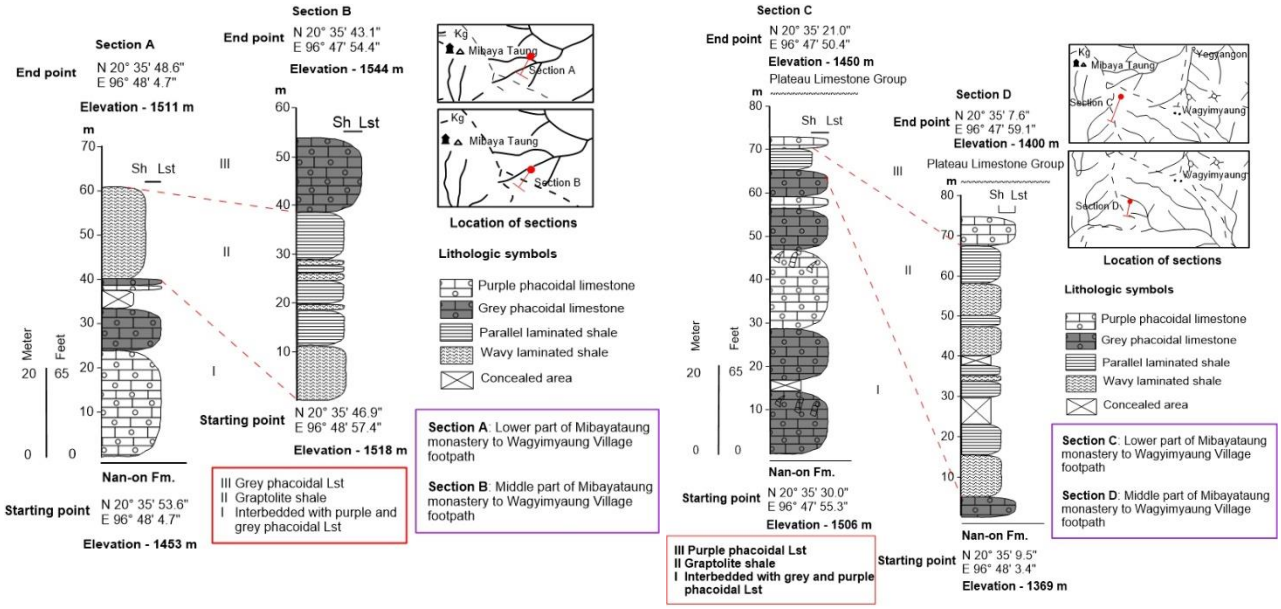
Section A
End point N 20° 35' 48.6" E 96° 48' 4.7"
Elevation - 1511 m
Sh Lst
Nan-on Fm.
Starting point N 20° 35' 53.6" E 96° 48' 4.7"
Elevation - 1453 m
Section B
End point N 20° 35' 43.1" E 96° 47' 54.4"
Elevation - 1544 m
Starting point N 20° 35' 46.9" E 96° 48' 57.4"
Elevation - 1518 m
III Grey phacoidal Lst
II Graptolite shale
I Interbedded with purple and grey phacoidal Lst
Kg
Mibaya Taung
Section A
Section B
Location of sections
Lithologic symbols
Purple phacoidal limestone
Grey phacoidal limestone
Parallel laminated shale
Wavy laminated shale
Concealed area
Section A: Lower part of Mibayataung monastery to Wagyimyaung Village footpath
Section B: Middle part of Mibayataung monastery to Wagyimyaung Village footpath
Section C
End point N 20° 35' 21.0" E 96° 47' 50.4"
Elevation - 1450 m
Plateau Limestone Group
Sh Lst
Nan-on Fm.
Starting point N 20° 35' 30.0" E 96° 47' 55.3"
Elevation - 1506 m
Section D
End point N 20° 35' 7.6" E 96° 47' 59.1"
Elevation - 1400 m
Plateau Limestone Group
Sh Lst
Nan-on Fm.
Starting point N 20° 35' 9.5" E 96° 48' 3.4"
Elevation - 1369 m
III Purple phacoidal Lst
II Graptolite shale
I Interbedded with grey and purple phacoidal Lst
Yegyangon
Wagyimyaung
Section C
Section D
Section C: Lower part of Mibayataung monastery to Wagyimyaung Village footpath
Section D: Middle part of Mibayataung monastery to Wagyimyaung Village footpath

Figure (7 & 8) Individual correlation sections of the Linwe Formation
(Modified after Ye Yint Aung, 2015)

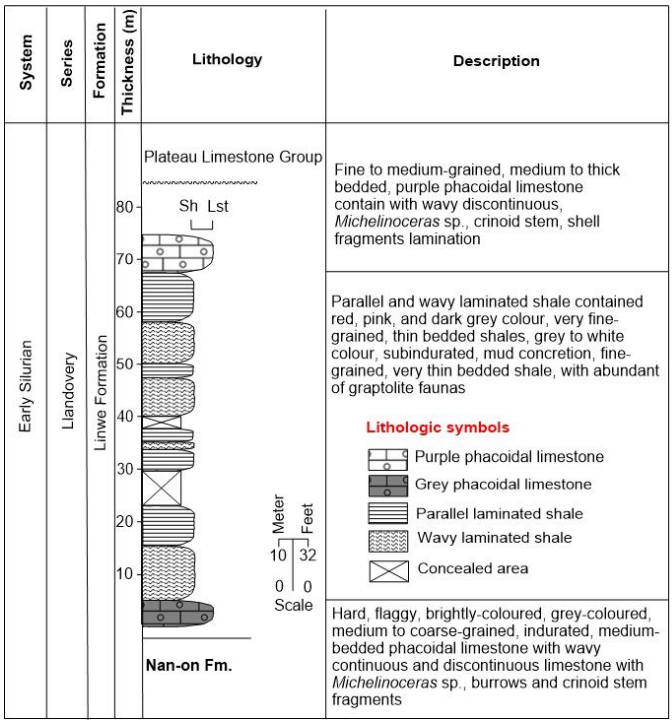

Figure (9) Composite section of the Linwe Formation (Modified after Ye Yint Aung, 2015)

Faunal Content

Michelinoceras sp., crinoid stems, inclined burrow, and other shell fragments are observed in the phacoidal limestone. Graptolites are common in graptolite shale such as *Monograptus convolutus*, *Monograptus cyphus*, *Monograptus triangulatus*, *Monograptus incommodus*, *Monograptus clintonensis*, *Monograptus millepeda*, *Monograptus gregarious*, *Monograptus sedgwicki*, *Petalograptus folium*, *Monograptus turriculatus*, *Monograptus priodon*, *Monograptus lobiferous*, *Rastrites* sp., *Rastrites peregrine*, *Orthograptus vesiculosus*, *Mesograptus modestus*, *Climacograptus typicalis* var. *Atlanticus*, *Climacograptus rectangularis* *Climacograptus parvus*.

Age and Correlation

According to graptolites and stratigraphic sequence, the age of the Linwe Formation is considered as the Early Silurian (Llandoverian) age. It can be correlated with the Nyaungbaw Formation of northern Shan State (Myint Lwin Thein, 1973) and the *Camerocrinus*-bearing Lower Jenhochian Formation of Yunnan (Sun, 1948). Moreover, Linwe Formation of this area can be correlated with the Setul Limestone Formation in the Langkawi islands near the Thailand-Malayan border (Myint Lwin Thein, 1973).

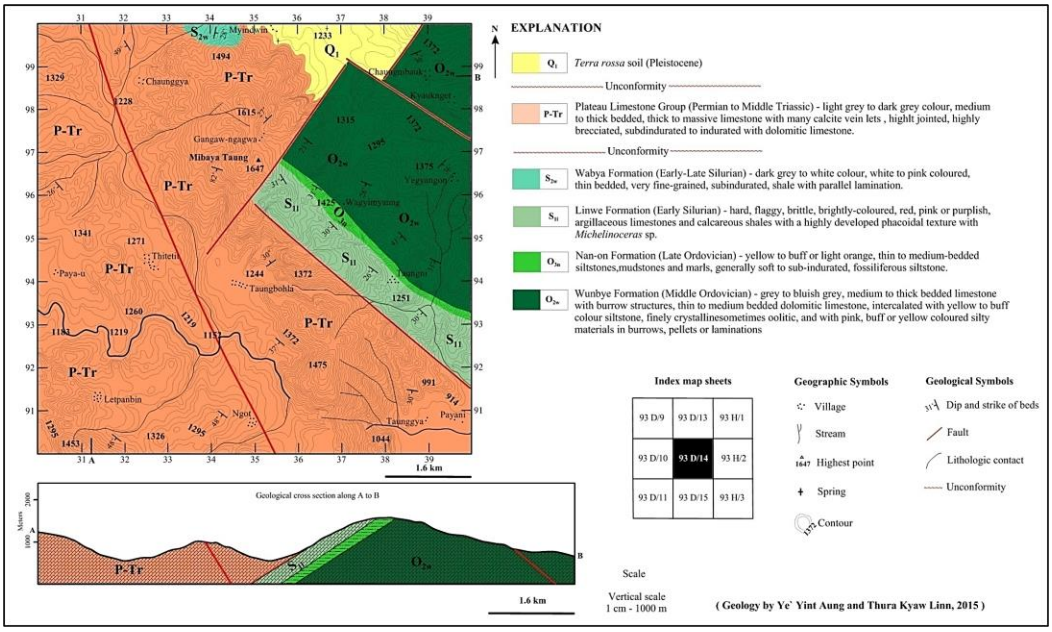
EXPLANATION
Terra rossa soil (Pleistocene)
Unconformity
Plateau Limestone Group (Permian to Middle Triassic) - light grey to dark grey colour, medium to thick bedded, thick to massive limestone with many calcite vein lets , highlt jointed, highly brecciated, subdindurated to indurated with dolomitic limestone.
Unconformity
Wabya Formation (Early-Late Silurian) - dark grey to white colour, white to pink coloured, thin bedded, very fine-grained, subindurated, shale with parallel lamination.
Linwe Formation (Early Silurian) - hard, flaggy, brittle, brightly-coloured, red, pink or purplish, argillaceous limestones and calcareous shales with a highly developed phacoidal texture with Michelinoceras sp.
Nan-on Formation (Late Ordovician) - yellow to buff or light orange, thin to medium-bedded siltstones,mudstones and marls, generally soft to sub-indurated, fossiliferous siltstone.
Wunbye Formation (Middle Ordovician) - grey to bluish grey, medium to thick bedded limestone with burrow structures, thin to medium bedded dolomitic limestone, intercalated with yellow to buff colour siltstone, finely crystallinesometimes oolitic, and with pink, buff or yellow coloured silty materials in burrows, pellets or laminations
Index map sheets
93 D/9
93 D/13
93 H/1
93 D/10
93 D/14
93 H/2
93 D/11
93 D/15
93 H/3
Geographic Symbols
Village
Stream
Highest point
Spring
Contour
Geological Symbols
Dip and strike of beds
Fault
Lithologic contact
Unconformity
Myindwin
Chaunggya
Gangaw-ngagwa
Mibaya Taung
Thitetu
Paya-u
Taungbohla
Letpanbin
Ngot
Yegyangon
Wagyimyaung
Payant
Taunggya
P-Tr
1.6 km
Geological cross section along A to B
Scale
Vertical scale
1 cm - 1000 m
(Geology by Ye` Yint Aung and Thura Kyaw Linn, 2015)

Figure (10) Geological map of the Mibayataung area, Southern Shan State
(Geology by Ye Yint Aung and Thura Kyaw Linn, 2015)

The five lithostratigraphic units are included in the study area (Figure - 10). The Ordovician unit of Wunbye Formation is widely distributed around the Yegyangon and Wagyimyaung villages. Nan-on Formation is narrow exposed in the southeastern part of the study area. The Silurian unit of Linwe Formation is well exposed in southeastern part and Wabya Formation is exposed around the Myindwin village. Plateau Limestone Group is dominated rock unit in the study area and it is mainly covered western and southeastern part.

Systematic Paleontology

Type materials were deposited and stored at the Department of Geology, Hinthada University. All graptolite species were collected from the southeastern part of Mibayataung area (Figure - 11). In this section, all illustrated graptolites are no new term and graptolite classification followed by Treatise on Invertebrate Paleontology (Moore, 1952 and 1955).

Phylum - PROTOCORDATA Bulman, 1970

Class - GRAPTOLITHINA Bulman, 1970

Order - GRAPTOLOIDEA Lapworth, 1873

Family - MONOGRAPTIDAE Lapworth, 1873

Subfamily - MONOGRAPTINAE Lapworth, 1873

Genus - *Monograptus* Geinitz, 1852

Monograptus convolutus (Hisinger) 1837, Plate (1) (A)
Ruedemann (1947), Graptolites of North America
Pl. 87, Figure 2-6
Neaverson (1955) Straitgraphical Paleontology
Figure 34, No. 22

Material—The specimen (MB - 67) were collected from the grey to pinkish grey colour, sub-indurated shales of Linwe Formation along the Mibayataung monastery to Wagyimyaung village footpath, near the Wagyimyaung village.

Locality—*Monograptus convolutus* occurs at southeast of Mibayataung monastery, Mibayataung area, Kalaw Township.

Diagnosis—Rhabdosome coiled into flat spiral, slender, thecae of the proximal portion of the narrow, isolated *Rastrites* type, but those of the distal portion of the triangular in contact.

Description—The nearly complete rhabdosome coiled into a flat spiral and except at the distal extremity; slender but widening gradually for the first few whorls, then maintain a constant breadth of 1.5 cm, thecae are ten in 1.2 cm. The rhabdosome is a diameter of 1.1 cm. Aperture is unknown.

Discussion—This species mostly resembled to *Monograptus convolutus* (Hisnger) Neaverson, 1955, Figure 34, No. 22 and *Monograptus convolutus* (Hisinger) and *Monograptus spiralis* (Geinitz) Ruedemann, (1947), Figure 2-6 by its convolute rhabdosome, isolated and straight or triangular thecae and also resembles *Rastrites peregrines* (Barrande) Neaverson, 1955, but differs by more closed isolation of thecae.

Age—Early Silurian (Middle Llandovery)

Genotype - *Lamatoceras priodon* Bronn, 1835

Monograptus priodon Plate (1) (B)

(Bronn, 1835) Plate (VI), Figures 1-3

Neaverson, 1955.Stratigraphical Paleontology

Figure 5, No. 30

Morre, 1955. Treatise on Invertebrate Paleontology (V)

Graptolithina, Figure. 1 a-b

Material—Rhobdosome were collected from the white to yellowish or grey shale (MB - 8) of Linwe Formation and Wabya Formation along the footpath of Mibayataung to Wagyimyaung village. The specimen is complete.

Locality—*Monograptus priodon* occurs at the lowermost part of Linwe Formation along the footpath of Mibayataung monastery to Wagyimyaung village and near the east of Mibayataung hill, Kalaw Township. It is occurring at the Bendaung Formation, Llandovery age in north Malaysia.

Diagnosis—Uniserial, isolated and hooked thecae, aperture facing downward.

Description—Rhabdosome straight, uniserial, with thick thecae which narrows towards aperture, 28 thecae counted in 3.7 cm nearly uniform in isolation. The thecae are generally horizontal but slightly curved down. Apertures are facing outward or downward.

Discussion—This species having thick septum, hooked and isolated thecae is resembling to *Monograptus priodon* (Bronn) Neaverson, 1955. It differs from *Monograptus lobiferus* and *Monograptus millepeda* by having thecae are not recurved towards to septum and simply curved thecae with aperture facing outward or downward.

Age—Early Silurian (Llandovery)

Monograptus triangulatus Plate (1) (C)

(Harkness) Plate (VI), Figures (4-6)

Neverson, 1955 Stratigraphical Paleontology

Figure 5, No. 20

Material—The specimen (MB - 53) were collected form the light grey colour, discontinuous wavy laminated shale of Linwe Formation along the footpath of Mibayataung monastery to Wagyimyaung village. The specimen is almost complete and well preserved.

Locality—*Monograptus triangulatus* occurs at the lower part of Linwe Formation along the footpath of Mibayataung monastery to Wagyimyaung village and near the east of Mibayataung hill, Kalaw Township.

Diagnosis—Rhabdosome straight, uniserial, triangular shaped thecae with their extremities distinctly curved, nearly uniform in isolation, straight apertural margin and normal to the rhabdosome axis.

Description—Rhabdosome straight, uniserial with thick thecae. Twenty-one thecae counted in 2.3 cm, nearly uniform in isolation. The thecae have a marked triangular-shaped with their extremities distinctly curved. The aperture margins are nearly straight and normal to the rhabdosome axis. Septum thin and measured 0.5 cm. Rhabdosome wide about 2.8 cm and Length is about 0.25 cm. The sicula is not visible clearly.

Discussion—This species is almost resembled to the *Monograptus triangulatus* (Harkness) Neaverson, 1955. Figure 5, No. 20 by having triangular shaped with their extremities distinctly curved and the apertural margins are nearly straight and are normal to the rhabdosome axis. It differs from the *Monograptus convolutus* (Hisiger) by having triangular shaped, straight rhabdosome and its apertural margin are nearly straight and normal to the rhabdosome axis.

Age—Early Silurian (Llandovery)

Monograptus turriculatus Plate (1) (D)
(Barrande) Plate (X), Figures 1 & 2
Neaverson, 1955. Stratigraphical paltontology
Figure. 34, No. 24

Material—The specimen (MB - 57) were collected from grey to yellow colour, shale of Linwe Formation at Mibayataung monastery to Wagyimyaung village footpath.

Locality—*Monograptus turriculatus* occurs at Mibayataung area, Kalaw Township, southern Shan State.

Diagnosis—Rhabdosome spirally coiled, curl and spring-like thecae are triangulate and measured as 3 mm in the distal portion. Rhabdosome is 1.6 cm long and 1 cm wide at the proximal part and 0.5 cm in distal part.

Description—The nearly complete rhabdosome is spirally coiled, uniserial, thecae are triangulate and counted 3 mm in the distal portion. Rhabdosome is 1.6 cm long and 1cm wide at the proximal part and 0.5 cm in distal part. Thecae are simple and extremities of the apertural margin are very narrow and facing downwards.

Discussion—This species mostly resembles to *Monograptus turriculatus* (Barrande), Neaverson (1955) by having its spirally coiled rhabdosome and triangulated thecae.

Age—Early Silurian (Llandovery)

Subfamily - PETALOGRAPTINAE Bulman, 1955
Genus - *Petalograptus* Suess, 1851
Genotype - *Prionotus Folium* Hisinger, 1837

Petalograptus folium Plate (1) (E)
Hisinger, 1837 Plate (X), Figures 7 & 8
Moore, 1955 Treatise on Invertebrate Paleontology (V)
Graptolithina, Figure 63, 6a, 6b

Materials—The rhabdosome (MB - 17) were collected from light grey colour, slaty shales of Linwe Formation along the Mibayataung monastery to Wagyimyaung footpath. The specimen is almost complete with sicula.

Locality—*Petalograptus folium* occurs at the upper part of Linwe Formation near the Mibayataung hill, Kalaw Township.

Diagnosis—Small rhabdosome with an elongated outline, flattened and leaf-like. Thecae are long simple tube, nema, and having narrow median septum and sicula. Thecae overlap, orthocline, and also biserial.

Description—Rhabdosome measuring 2.6 cm in length and 0.6 cm in width, generally parabolic in outline, biserial thecae are long, 2.4 cm, slight bend outwards. Orthocline in simple tubes aperturally expanded. The inclination is approximately 35 degrees, increasing to proximal. The aperture is poorly concave and moderately inclines. Thecae are mostly overlap and counted about 9 in number. Sicula are conspicuous and right angle to the flattened rhabdosome. Length of sicula is about 3 cm and coiling at the uppermost part.

Discussion—This species is mostly to the *Petalograptus folium* Hisinger, 1837 and differs from the *Petalograptus minor* (Elles, 1897) by having closer inclination of thecae to the rhabdosome axis.

Age—Early Silurian (Llandovery)

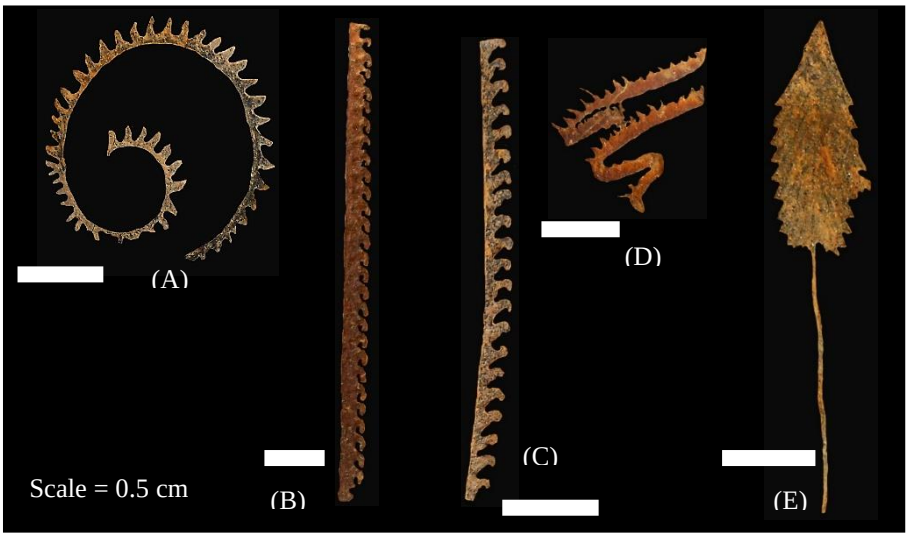

Plate (1) The graptolites from Linwe Formation: (A) *Monograptus convolutus,* X 2.4; [MB - 67] (B) *Monograptus priodon,* X 2.8; [MB - 8] (C) *Monograptus triangulatus,* X 3.3; [MB - 53] (D) *Monograptus turriculatus,* X 3.2; [MB - 57] (E) *Petalograptus folium,* X 2.9; [MB - 17].

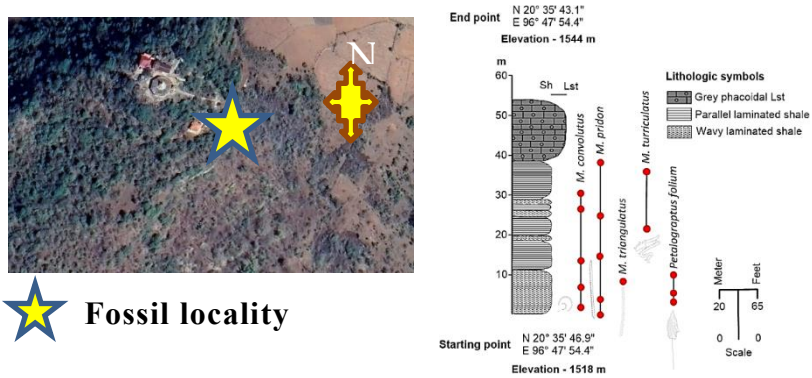

Figure (11) Distribution of Graptolite Faunas in the study area

Results and Discussion

The discovery of stratigraphical and paleontological aspects are described in this paper. The main section of this research is to highlight the systematical analysis on graptolites and it is exactly different with the graptolite biostratigraphy. Because systematic investigation is classifying each graptolite species and biostratigraphy is specification of biozones. Stratigraphically, three lithostratigraphic units of Wunbye Formation, Nan-on Formation, and Linwe Formation were distributed in the Mibayataung area, by Chit Sein (1998). In addition, the two lithostratigraphic units of Wabya Formation and Plateau Limestone Group are found in the study area, by Ye Yint Aung (2015). The main result of five graptolites species including; *Monograptus convolutus*, *M. priodon*, *M. triangulatus*, *M. turriculatus* and *Petalograptus folium*. *Petalograptus folium* is different species of Linwe Formation and remain of other species are similar according to the discovery of the previous author. This finding is also particularly important for stratigraphy, paleontology and paleoecology. Furthermore, it can be used as a reference for final year students and fossil records are large portion of the Early Paleozoic timescale and used by many geoscientists and biologists.

Conclusion

The goal of the present study is to analyse systematic paleontology of graptolite faunas. The total of five lithostratigraphic units were found in the study area. Linwe Formation can be divided into two distant units: (i) Phacoidal limestone (ii) Graptolite bearing shale. Phacoidal Limestone is divided into two subunits. They are purple phacoidal limestone and grey phacoidal limestone. The graptolites are the most abundant fauna and the *Michelinoceras* sp. is an unique feature of Linwe Formation. Five species of graptolite fossils are mentioned in this paper.

Acknowledgement

This study was based on my MSc Thesis (2015). We would like to express our sincere gratitude to Dr. Myat Nyunt, Rector of Taungoo University, Dr. Mi Mi Soe and Dr. Htar Lwin, Pro-Rectors of Taungoo University for their encouragement to carry out this paper. Special thanks to Dr. Aye Thidar Mon, Professor and Head of the Department of Geology, Taungoo University for her enthusiastic help. We extremely grateful to Ethic Review Committee (ERC), Department of Geology, Taungoo University for their review. Thanks are also due to colleagues at the Department of Geology, Taungoo University for their help throughout the study.

Conflict of Interest

The authors declare no conflict of interest regarding the publication of this paper.

References

Barrande J. (1850) Graptolites du Boheme, 74pp. Privately printed, Prague.

Bender, F. (1983) Geology of Burma: In: Beitrage zur Regionalen Geologie der Erde, Band 16. Gebruder Borntraeger Berlin, 1-261. https://dio.org/10.1017/S0016756800029447.

Bronn, H.G. (1835) Lethaea geognostica, v. 1. Stuttgart, E. Schweitzerbart'sche. 768 pp. http:// dio.org/10.5962/bhl.title.59080

Brown, J.C. & Sondhi, V.P. (1933) The Geology of the country between Kalaw and Taunggyi, southern Shan State, Burma: *Rec. Geol. Surv. India*, **67** (2):166-247. http;//mem. lyellcollection. org/content/48/1/1.1

Bulman, O. M. B. (1970) Graptolithina with sections on Entero-pneusta and Pterobranchia, V5 V163. InTEICHERT, C. (ed.) Treatise on Invertebrate Paleontology, Part V, Graptolithina.163 pp. Geological Society of America & University of Kan-sas Press, Boulder & Lawrence. https://www.goodreads.com/book/show/2753645-treatise-on-invertebrate-paleontology-part-v

Chit Sein (1998) Systematic and stratigraphic paleontology of Silurian fossils assemblages (Graptolites) of Wabya, Kyauktap and Mibayataung areas, southern Shan State. (Unpublished) M.Sc. Thesis, Department of Geology, University of Yangon, 104 pp.

Elles, G. L. (1897) The subgenera *Petalograptus* and *Cephalograptus*. *Quarterly Journal of the Geological Society of London* 53: 186–212. http://dio.org/10.1144/GSL.JGS. 1897.05. 3.01-04.15.

Garson, M.S., Amos, B. J. & Mitchell, A.H.G. (1976) The geology of the area around Neyaungga and Ye-ngan, southern Shan State, Burma: *Overseas Mem., Inst. Geol. Sci.*, **2**: 1-77. https://searchworks.stanford.edu/view/914637.

Geinitz, H.B. (1852) Die Versteinerungen der Grauwacken Formation (Die Graptolithen). Verlag Wilhelm Eugelman, Leipzig. 58 pp. http://www.zobodat.at/pdf/Mitteilung-Osterlande-Altenburg-NS-5-1892-0161-0199.

Hisinger, W. (1837) *Lethaea Suecica, seu petrificata Sueciae, iconibus et characteribus illustrata. Supplementum* 1:1.124, Stockholm.

Hla Thein (1991) Lower Silurian Graptolites from Pyin-Oo-Lwin Area: Georeport, 1:11-22.

Kaung Sithu (2014) A Study on the Paleontological Aspects of Paleozoic Rocks in the Yegyanzin area, southern Shan State, Myanmar (Unpublished), M.Sc. Thesis, Department of Geology, Hinthada University.

Kyi Soe (1983) *Paleozoic Faunal Study and Biostratigraphy of Yechanbyin-Linwe Area, Ye-ngan Township, southern Shan State*; (Unpublished) MSc, Thesis, Rangoon Arts and Science University.

Lapworth, C. (1873) On an improved classification of the Rhabdophora. Geological Magazine 10: 500-504; 555-560, London.

Moore, R. C. (1952) Treatise on invertebrate paleontology. Report to Paleontology Society Council, 44 p. 285.

Moore, R.C. (1955) Treatise on Invertebrate Paleontology, Part V, Graptolithina. Kansas, Geol. Soc. Am. University of Kansas Press. https://www.amozon.com/Treatise-Invertebrate-Paleontology-Part-Pterobrachina/dp/B001WNH008.

Myint Lwin Thein (1973) The Lower Paleozoic stratigraphy of western part of the Southern Shan States, Burma - *Bull. Geol. Soc. Malaysia*, **6**: 143-163. https://gsm.org.my/products/702001-101349-pdf

Neaverson, E. (1955) Stratigraphical Palaeontology. A Study of Ancient Life Provinces. Clarendon Press, Oxford. https://www.ebay.com/itm/252431033264.

Ohmar Soe Yin *et al.* (2021) Comparative Study of Graptolite Faunas in Pyin Oo Lwin area, Mandalay Region and Pindaya area, Shan State (south), *Proceeding of the 4th International Conference on Substantial Scientific Collaboration of Ocean and Earth Science between Myanmar and China*, 14-22.

Reed, F. R. C. (1936). The Lower Paleozoic faunas of Southern Shan States, *Palaeont. Indica, N.S.*, 21(3): 130 pp. 7 pl.; Calcutta.

Ruedemann R. (1947) Graptolites of North America Geological Society of America, Memoir 19, 1-652. https://doi.org/10.1130/MEM19-p1.

Suess, E. (1851) Uber bohmische Graptolithen. *Haidingers Berlin* 4:89-134. https://www.worldcat.org/title/uber-bohmische-graptolithen/oclc/81401447

Sun, Y. C. (1948) Problems of the Paleozoic stratigraphy of Yunnan. -50th Ann. Pap., Nation. Peking Univ., Geol. Scr.: 1-27.

Wolfart, R. *et al*. (1984) Stratigraphy of western Shan Massif, Burma: *Geologishes Jahrbuch, Hannover*, **57**: 3-92.https://www.schweizerbart.de/publications/detail/isbn/9783510962884/Geologisches-Jahrbuch- Reihe-B-Heft.

Ye Yint Aung (2015) An Analysis of the Biostratigraphy of the Paleozoic and Mesozoic unit in the Mibayataung area, Kalaw Township, Southern Shan State; (Unpublished), M.Sc. Thesis, Department of Geology, Hinthada University.